ULTRAFAST X-RAY SCIENCE:
A NEW FRONTIER FOR NEXT GENERATION LIGHT SOURCES

R. W. Schoenlein[1], H.H.W. Chong[1,2], T. E. Glover[3], P.A. Heimann[3],
C.V. Shank[1,2], A. Zholents[4], M. Zolotorev[4]

[1]Materials Sciences Division, Berkeley National Laboratory, Berkeley, CA 94720 USA
[2]University of California Berkeley, Berkeley, CA 94720, USA
[3]Advanced Light Source, Berkeley National Laboratory, Berkeley, CA 94720 USA
[4]Accelerator and Fusion Research Division, Berkeley National Laboratory, Berkeley, CA 94720 USA

Our scientific understanding of the static or time-averaged structure of matter on the atomic scale has been dramatically advanced by direct structural measurements using x-ray techniques and modern synchrotron sources. However, the structure of matter is not static, and to understand the behavior of matter at the most fundamental level requires structural measurements on the time scale on which atoms move. The evolution of matter structure is dictated by the making and breaking of chemical bonds and the rearrangement of atoms, and this occurs on the fundamental time scale of a vibrational period, ~100 fs. Atomic motion on this time scale ultimately determines the course of phase transitions in solids, the kinetic pathways of chemical reactions, and even the efficiency and function of biological processes. A thorough understanding of such dynamic behavior is a first step to being able to control structural evolution, and will have important scientific applications in solid-state physics, chemistry, materials science, AMO physics, and biology.

At present, our ability to measure and understand fundamental structural dynamics is limited by lack of suitable femtosecond x-ray sources. Femtosecond lasers operating on the 10 fs scale are widely used to study ultrafast processes in numerous fields of research. In condensed matter systems however, visible photons are not effective as structural probes since they interact with electronic states extending over multiple atoms. On the other hand, x-ray photons can provide the requisite structural information and this is driving the emergence of ultrafast x-ray science as a new field of research in which x-ray techniques such as diffraction and EXAFS are used in combination with femtosecond lasers and applied in a time-resolved manner to probe structural dynamics.

This talk will discuss anticipated scientific applications for two femtosecond x-ray beamlines that are being developed at the Advanced Light Source [1-3] as well as future scientific applications and the requirements they place on next generation light sources providing ultrashort x-ray pulses.

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Submitting author: R.W. Schoenlein, e-mail: rwschoenlein@lbl.gov, FAX: (510) 486-5530